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Study On Numerical Simulation of the Arrangement about Mining Roadway with Short Distance

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Abstract

Based on numerical simulation test and test results, the stability of bare roadway with different staggered distance was studied. Conclusions can be drew as follows: Of these ulter-closed mining roadway arrangement modes, global stability of the inboard type roadway is better based on the aspects of degree of damage; Roof subsidence in the inboard-type roadway is smaller, offset at two sides of roadway is larger, its offset direction approaches toward the centre of roadway, and offset increases with staggered distance decreases, the supporting of two sides is the central difficulty for in-board type roadway; The degree of damage in overlapping-type roadway is larger, and roof subsidence of overlapping-type is similar with the inboard-type roadway, while the deformation is large at left side, there are few changes at right side. The destructive deformation is maximum when the staggered distance of outward-type roadway is 2m, and degree of damage is decreases with the increase of staggered distance in outward-type roadway. Overall, roof subsidence in the outward-type roadway is larger, and two sides of it are basically stable.

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Key words：short distance；mining roadway；numerical simulation；staggered distance

1 INSTRUCTION

In underground mining,the importance of roadway is obvious,all basic activities like conveyance,ventilation and pedestrians etc.In mining need to be completed through roadway.Therefore,the research about it has gotten universal attention both at home and abroad.There are mainly 3 kinds of arrangement forms about mining roadway in the coal seam mining with short distance: overlapping-type roadway, inboard-type roadway, and outward-type roadway.Among those research about arrangement forms of the 3 kinds of roadway at home and abroad,which mostly concentrate on only 1 kind roadway arrangement form,there is little systematic research on arrangement form about the 3 kinds of roadways. In

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our study, we take the Lu An Group mine field for the model and study systematically the 3 kinds of arrangement forms about mining roadway with short distance by the means of numerical simulation.

2 GEOLOGICAL SITUATION OF CONSTRUCTION

15-1# formerly called the third coal,knowns as " two section coal";is the top layer for the 15# coal group,4.38m from the bottom of K_2 limestone and 4.19m from the 14# coal layer,the thickness is 0-1.5mm,and the average one is 0.95m,band coal occasionally,which is the main mining layer in this area.

15-2# average thickness is 0.56m,simple structure,belongs to instability coal layer.

15-3#: formerly called the first coal,knowns"four section coal",one of the mining layers in the whole area,belongs to the lowest layer of the 15# coal group.For the average thickness,0-3 band coal layers,complex structure,but belongs to stable coal seam.

As the roof and floor of plate in 15# coal seam groups depicted above the strata bar graph(see table1).The direct roof is mainly mud stone,sandy mud stone,carbonaceous mud stone,1.5-4.91m for thickness,3.31m for average thickness,main roof are limestone,5.09-11.76m for thickness,7.12m for average thickness.The immediate roof is mainly mud stone,locally sandy mud-stone, carbonaceous mud-stone,0.3-7.08m for thickness,3.82m for average thickness. Old bottom plate just develop foe partly ,is medium sandstone and silty sandstone,0.2-3.76m for thickness,1.91m for average thickness .

Table1 strata bar graph of roof and floor in 15#coal seam group

columnar	Name	Thickness（m）	Rock of description
	Medium-grained sandstone	8.90～24.10 11.60	The main of medium-grained quartz arkose,partly is sandy mudstone and mudstone,fossil plants
	K_2limestone	5.09～11.76 7.12	Dense,hard,Contain calcite crystal and veinlet,karst cave, animal fossil
	14#coal	0～2.10 0.72	not mining Coal layer
	mudstone	1.57～7.44 3.77	Dense,Brittle,contain pyrite nodules,partlyiscarbon mudstone，fossil plants
	15-1# coal	0～1.55 0.95	Mining Coal Layer
	mudstone	1.10～3.49 1.96	Black,contain fossil plants andpyrite,partly is carbon mudstone
	15-2# coal	0～1.10 0.56	not mining Coal Layer
	Medium-grained sandstone	0.90～5.30 1.90	Gray-black,mainly is medium-grained quartz feldspar,partly is mudstone
	15-3# coal	0～2.42 1.59	Mining Coal Layer
	mudstone	0.27～8.67 5.06	Black,contain fossil plants,partly is siltstone and sandy mudstone
	alum clay mudstone	2.70～18.20 9.70	White Gray,Dense,with slip surface,with slip sence,With oolitic structure,a llittle pyrite.

3 NUMERICAL SIMULATION

3.1 Numerical Simulation Software

Numerical simulation methods mainly include finite element method and distinct element method.For the rock which has obvious bedding plane and joint surface and affected by the low-stress only, distinct element method has rapid development in recent years and has been applied much more.It is considered that Professor Wang Yong Jia as the representative in domestic,distinct element method also get considerable development.The DEM (Distinct element method) is a special distinct element method procedure which was proposed by Cundall and Strack(1979) who used deformation contact and the initial motion equation of display, time domain (not the transform, block equation).Internationally,the UDEC(Universal Distinct Element Code)is one of currently- accepted and effective ways for the numerical simulation of jointed rock mass. UDEC is used to simulate non-continuous media (such as joint fissure in the rock, etc.) to withstand static or dynamic loads ‘response. Non-continuous media is expressed by discrete collection of blocks.Discontinuous plane is processed as the boundary surface between blocks,allowing the block to have larger displacement and rotation along the discontinuous plane. Block can be rigid body or deformable body.Deformation block is divided into finite element mesh, and each unit exhibits linear or nonlinear characteristics according to the given criterion of "stress - strain". Normal and tangential relative movement on the discontinuous plane are also controlled by relationship of linear or nonlinear "force - displacement". Systematically speaking, UDEC is a deformation and large displacement which can well simulate block system, which is based on the "Lagrangian" algorithm.

3.2 The Determine Of Coal Rock Mechanics Parameters

The physical mechanical parameters of coal rock in the numerical simulation calculation come from the laboratory tests mainly come from the laboratory tests.At mean time,because the natural rocks are rich with joint and weak plane,its mechanical parameters are usually much smaller than the mechanical parameters of terrane block used in laboratory.Therefore,the mechanical parameters of terrane block we valued is 1/2～1/20 of the test results.And mechanical parameters in the numerical simulation are showed in table 2 an table 3.

Table 2 Physico-mechanical parameters of terrane block

lithology	bulk modulus/(10^{10}Pa)	shear modulus/(10^{10}Pa)	cohesion /MPa	internal friction angle/(°)	tensile strength /MPa
limestone	9.88	8.65	10.7	56.0	17.54
sandy mudstone	4.89	3.91	2.80	32.0	6.65
mudstone	4.67	3.72	2.74	30.0	6.40
Medium-grained sandstone	6.00	5.44	6.42	50.0	12.20
Grey rock	5.67	4.76	5.54	45.0	10.43
alum clay mudstone	3.21	1.98	1.26	30.0	4.68
Coal seam	0.27	0.12	1.34	30.0	2.06

After finishing the cutting of all the block (joints) and the dividing of the deformation units,we should add the boundary and initial conditions.Upper vertical direction uniform load is taken 7140.238kN·m^{-2} The underside contact face is settled boundary condition,the left and right contact face is calculated by side pressure coefficient 0.5 besides the settled boundary condition, the uniform load of the horizontal direction is 3570.119kN·m^{-2}.

Table 3 Mechanical parameters of terrane block contact face

lithology	normal stiffness/(10^{10}Pa)	tangential stiffness/(10^{10}Pa)	cohesion/ MPa	internal friction angle/(°)	tensile strength/MPa
limestone	1.00	0.80	0.97	26.0	13.26
sandy mudstone	0.73	0.40	0.81	13.0	5.65
mudstone	0.67	0.40	0.78	11.0	6.40
Medium-grained sandstone	0.80	0.70	0.35	20.0	9.20
Grey rock	0.9	0.76	0.54	20.8	8.43
alum clay mudstone	0.41	0.38	0.26	6.0	4.40
Coal seam	0.03	0.01	0.14	10.0	1.06

3.3 Simulation Program

According to geological data,model is built by 80m (length)×45m(height) as is shown in figure 1.Figure 1(a) is the distribution of each stratigraphic horizon,figure 1(b) is the strata model which is after-division of the block joints.According to the arrangement of inboard-type,overlapping-type,and outward-type of mining roadway with short distance,we excavated totally 9 arrangement models as follows: inboard-type with staggered distance are 8m,6m,4m,2m,and0m,(overlapping-type),outward-type with staggered distance are 2m,4m,6m,and 8m.Figure1 show inboard-type with staggered distance 8m,staggered distance 0m,(overlapping-type) and outward-type with staggered distance 8m,roadways arrangement model.In roadway arrangement models we take the commonly used rectangular tunnel and in order to get reasonable staggered distance,we used bare model and its size is 4m (length)×2.5(height).

When model is excavated, upper coal seam (15-1$^{\#}$)and its mining gateway are excavated together,mining gateway of lower coal seam(15-3$^{\#}$) is excavated according to different forms and staggered distance.Figure 2 show the inboard -type with staggered distance 8m,over-lapping type and outward type with staggered distance 8m excavation models.We can see the stress-train situation of the lower coal seam mining gateway and its interaction with upper coal seam mining gateway after sufficient calculation.In addition,in order to further study the deformation about the roof and two sides of the lower coal seam mining gateway,we conduct points observation at roof and the center of 0.5m at two sides of mining gatewayis model respectively,and as Figure 2 show the observation point A, B,C.

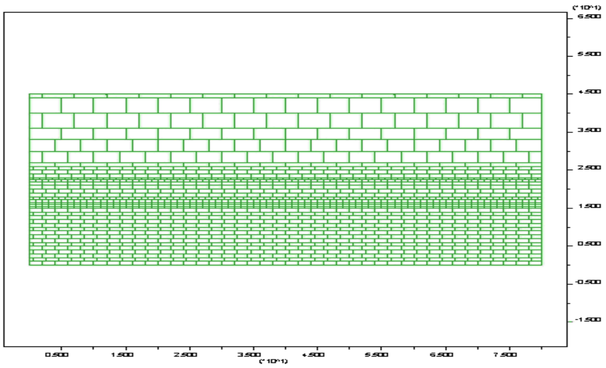


Fig1: the model of coal seam hosting

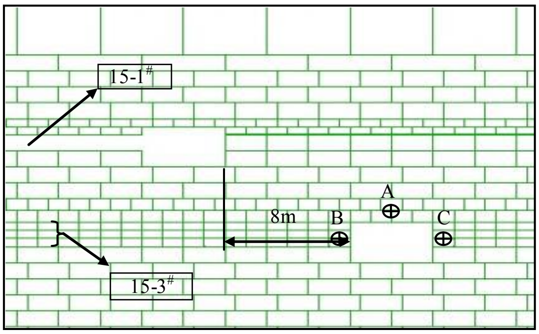


Fig2: the model of arrangement about mining roadway with short distance

3.4 Analysis of numerical simulation result

3.4.1Analysis of destructive degree about surrounding rock of roadway

The destructive effect about 3 roadway arrangement forms and 9 staggered distance models are showed in figure 3,and (a)--(i) in figure 3 are correspond the followings: inboard staggered distance

8m,6m,4m,2m,0m,and outward staggered distance 2m, 4m,6m,8m about roadway models,and the text below are all illustrated according to this corresponding relation.

Totally,4 models of inboard arrangement like figure 3 (a),(b),(c)and(d) have small deformation and are more stable compared with over-lapping model like (e) and the other 4 kinds of models for outward-type arrangement.In these 3 kinds of roadway arrangement forms,both over-lapping and outward arrangement roadway have larger deformation and destructive effect.Offset about both sides of inboard-type roadway is a little large,approaching the centre of the roadway,and for both sides of outward-type roadway,the offset is relatively smaller.

Just see the 4 kinds of models of inboard-type roadway.There is little destructive deformation about lower coal seam roadway,and roof deformation of roadway has few differences among them,but both sides have evident changes compared with the outward-type roadway.This small destructive deformation of inboard-type roadway also justify the theory that upper coal seam failure in goaf and then forms stress arch.The stress then is delivered centrally to the arch foot that protects coal pillar,which can make destructive deformation of inboard-type roadway smaller.

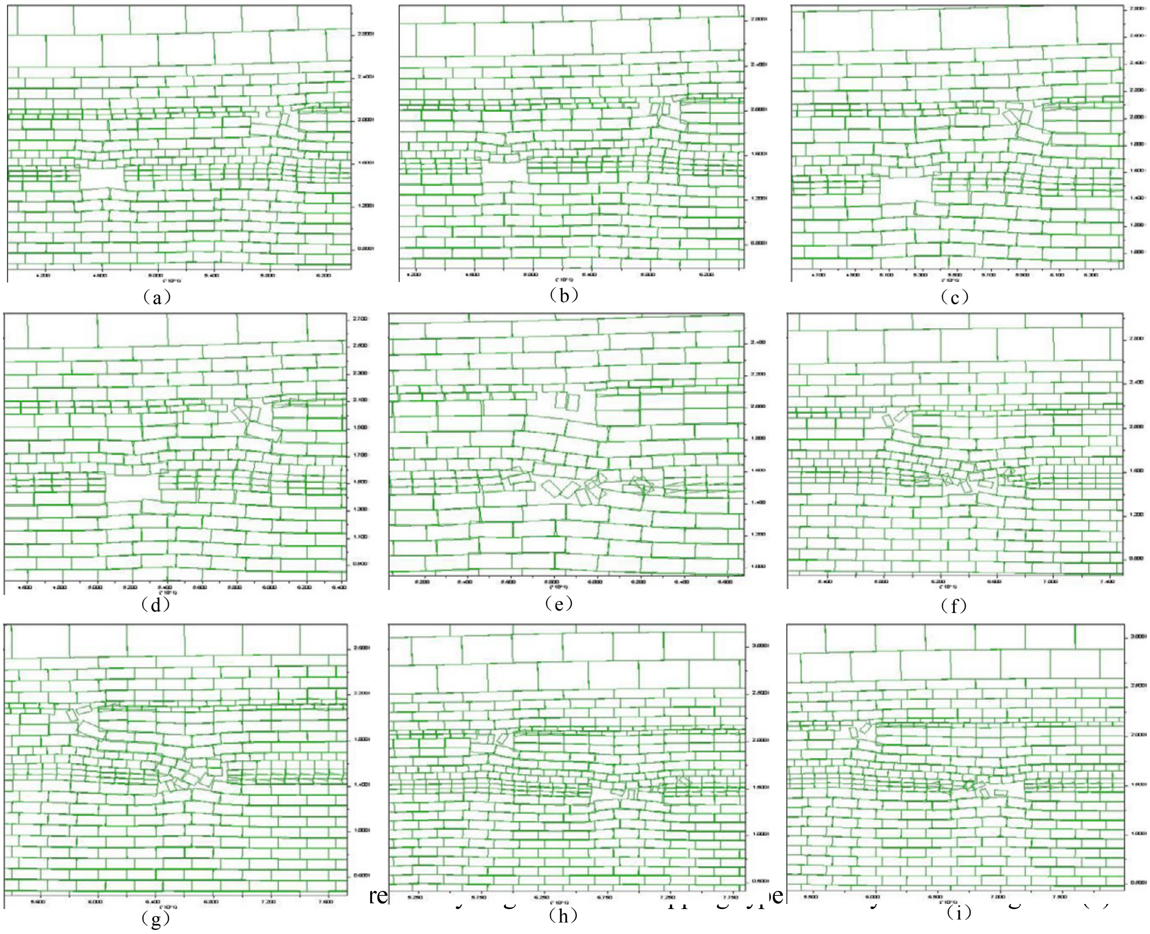


Fig.3: the destructive effect of mining roadway with diffent staggered distance

In lower coal seam roadway below the goaf,the horizontal destructive depth at one side is about1m,and about 1.8m at the other side, supporting of both sides is difficult.While roof of roadway has large deformation,there is no destruction,which keeps totally intact,and is not difficult to support. It is analyzed that it may be due to different excavation of overburden strata at two sides of roadway,in addition,the roof can keep totally stability may be due to the overlapping arrangement of upper and lower coal seam roadway,the upper coal seam roadway alleviates the stress vertically on the lower coal seam roadway.

Large destructive deformation of roadway roof is common phenomenon for outward type mining roadway according to the 4 models of outward roadway forms.The destructive deformation is more obvious with decrease of staggered distance.There is large destructive deformation at the roof and two sides for the roadway models whose outward staggered distance is 2m and 4m, which is hard to maintain.Two sides can still keep basically intact when outward staggered distance is 6m and 8m respectively,but the roof subsidence is relatively larger.

3.4.2 Stress Analysis Of The Roadway Surrounding Rock

Of the analysis of stress about each model,we mainly choose the stress σ_y distribution and stress τ_{xy} distribution to study .

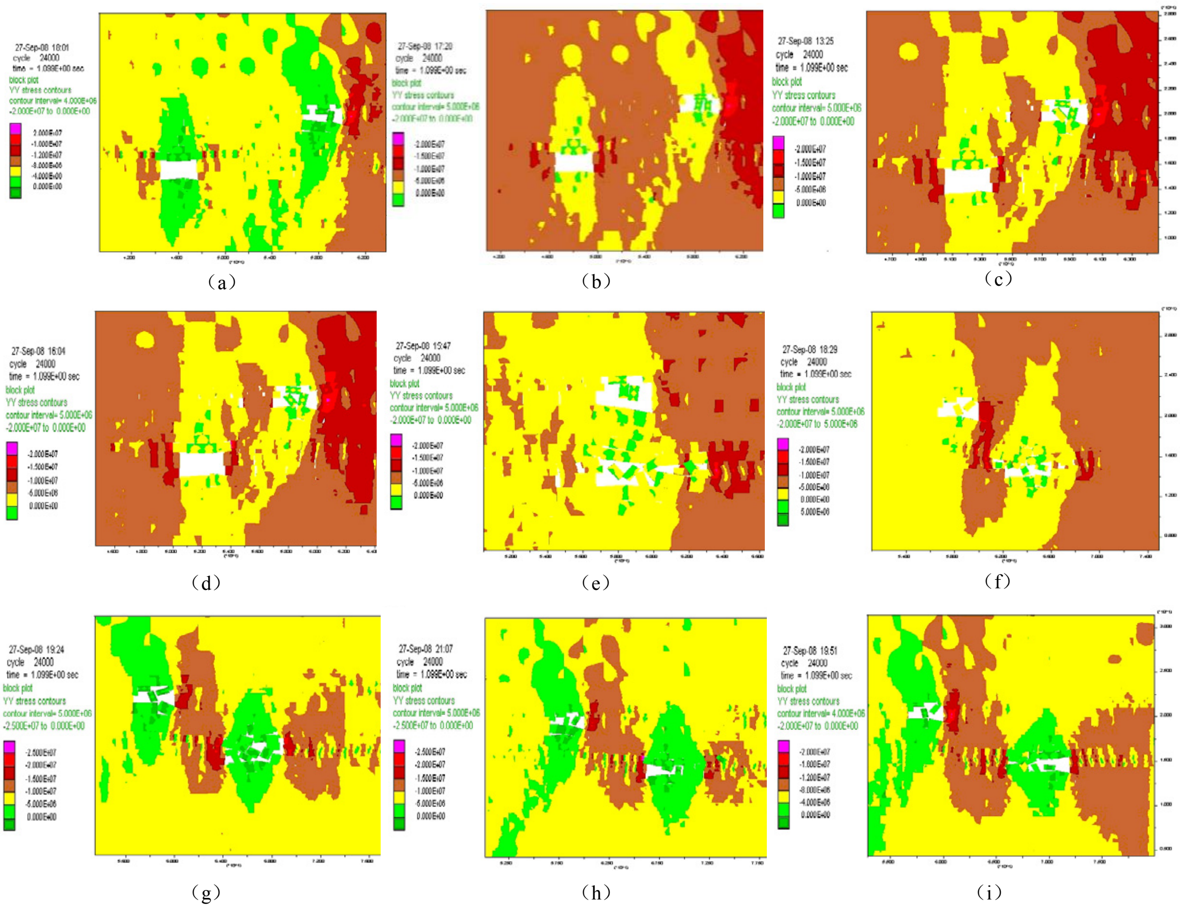


Fig4: the stress σ_y distribution of mining roadway with different staggered distance

Figure 4 mainly reflects the stress σ_y distribution of mining roadway,of the inboard type roadway models as showed in figure4(a),(b),(c),and(d), both the roof stress σ_y and floor stress σ_y of roadway are obviously smaller than the original rock stress 8MPa, generally 4-5MPa,and the roof subsidence is minimum when the in-board staggered distance is 8m,about 0-4MPa.Of the 4 models, the low stress range of the roof and floor increased with staggered distance decreased,and the low stress region of both the upper and lower roadway link together eventually.On the contrary, the stress σ_y of two sides of roadway is about 10-20MPa,which is obviously higher than original rock stress 8MPa.But what we should notice is the situation of high-stress distribution of two sides, this kind of high-stress contours line exhibits interval distribution,and the stress of low stress hand between high stress bands should be about 10MPa.Furthermore,the stress of high-stress region of two sides is the highest,16-20MPa.

Figure 4 (e) shows the stress σ_y distribution of overlapping-type roadway,which is divided into two stress regions and the regional boundaries between them is obvious. While stress in both upper and lower regions of roadway and the goaf at the left side of the roadway are 5MPa,stress in strata and entity coal at right side of roadway are generally 10MPa above.Stress is comparatively higher in entity coal at right side of roadway and strata,and the phenomenon of stress concentration is more apparent compared with in-board type.In this region,contour line interval distribution is also exist in the high stress region,the stress is 15-20MPa,however,the same distribution can not be found at the left side of mining roadway.

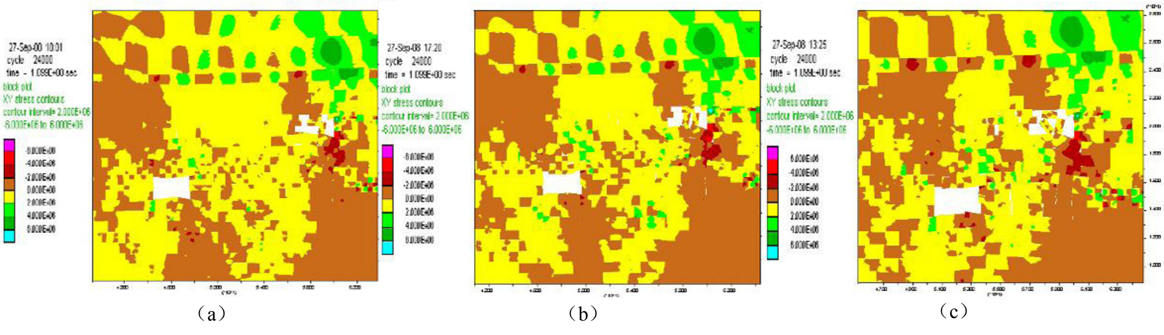
The stress σ_y distribution of outward-type roadway showed in the Figure4 (f),(g),(h),and(i) is similar with surrounding rock stress distribution of in-board type roadway,both roof and floor stress σ_y of roadway are smaller than original rock whose stress is 8 MPa,genarally 4-5Mpa； the stress σ_y at two sides of roadway is 10-20 Mpa. The difference is that a larger high-stress area is generated between left side of lower coal roadway and upper coal roadway,and the range of high-stress-area is larger with staggered distance increase.High-stress-area has interval distribution,higher stress, generally20 Mpa above.Besides,staggered distance of outward-type roadway has the similar inch with setting coal columns,stress of overlying strata all center on coal columns among staggered distances,stress at two sides of roadway is still large even the outward staggered distance is 8m.

Figure5 mainly reflects shear stress τ_{xy} distribution of roadway with different staggered distance.Of inboard-type roadway models showed in Figure5(a), (b), (c),and(d),stress τ_{xy} is generally 0-2Mpa,only some fragmentary parts can reach4MPa, and this kind of area is decrease with staggered distance increase.Figure5(e)is the stress τ_{xy} distribution of overlapping roadway,stress τ_{xy} of left side approaches 0,while stress τ_{xy} in the area of entity coal and rock at right side of roadway is relatively high, especially the large centralized range of the stress τ_{xy} in lower right of roadway, generally 2-4Mpa.Stress τ_{xy} of outward-type roadway as Figure5(f),(g),(h),and(i)show is higher compared with in-board type, the range of τ_{xy} mainly centre on the upper left and the lower right of roadway,and stress centralized range is relatively large,generally2-4 Mpa,and the highest stress can reach 6Mpa.Like inboard-type roadway,the larger staggered distance is,the less range of high-stress centralized will be.

3.4.3 Analysis of observation points about surrounding rock

Each roadway model has three observation points like A,B,and C,roof subsidence and offset of two sides of roadway are observed.Take inboard-type roadway model whose staggered distance is 8m for example,the three observation points record three parameters of roadway.(see Figure6)

Changes of relative subsidence of Point A which is 0.5m deep away the roof center in nine models are recorded,the final subsidence keeps steadily 0.8m when inboard-type roadway's staggered distance is 8m,6m and 4m,the final subsidence keeps steadily 1.0m when staggered distance is 2m,that is,roof subsidence of inboard-type roadway model is generally 0.8-1.0m;the final roof subsidence of overlapping-type keeps steadily 1.0m;when the staggered distance of outward-type is 8m,6m and 4m,the roof subsidence is 1.2m,1.4m and 1.8m accordingly,and when staggered distance of outward-type roadway is 2m,the roof is damaged severely,hard to balance the subsidence of roof,and we have no value about its subsidence.



(a) (b) (c)

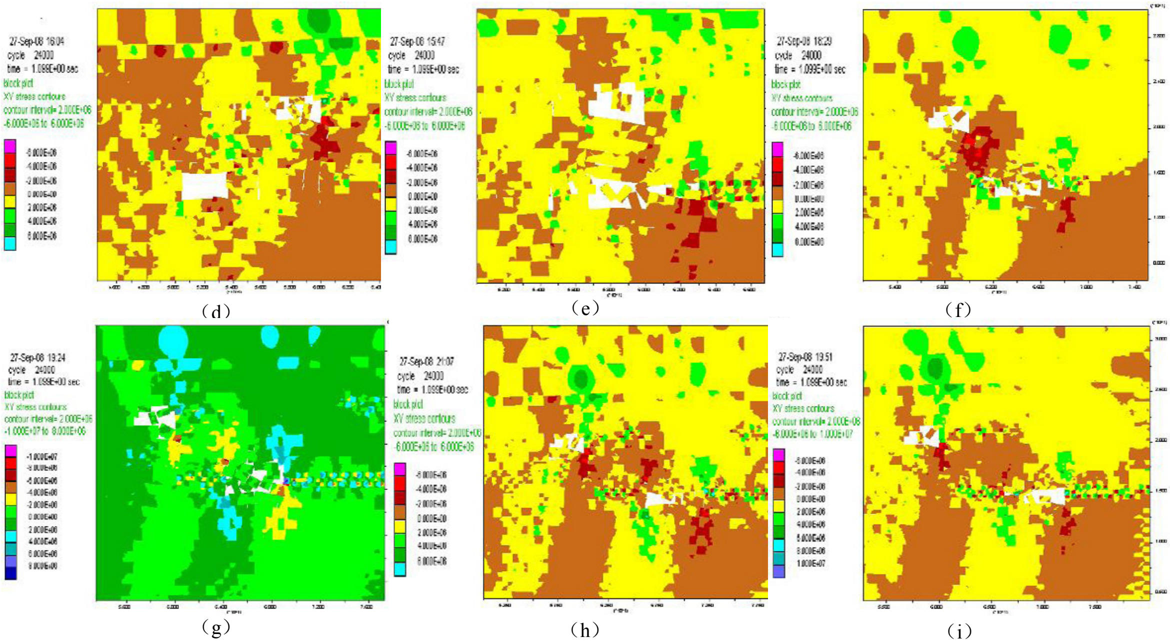


Fig5: the shear stress τ_{xy} distribution of mining roadway with different staggered distance

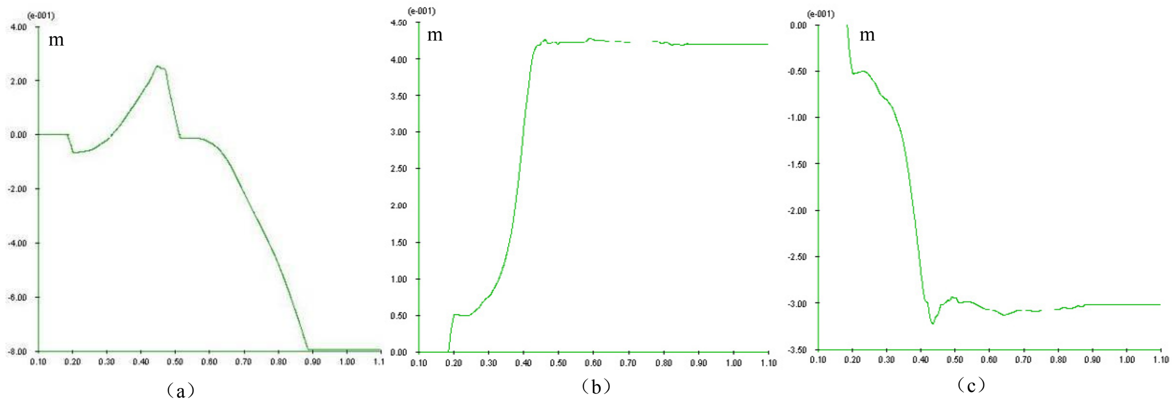


Fig6: the change curve of observation points in inboard-type roadway when the staggered distance is 8m

From above mentioned we can see,roof subdience in the outward-type roadway is larger,about 1.2-1.8m generally.In addition,during the process of sinking,the relative subsidence of roof point A in the in-board type roadway whose staggered distance is 8m subsides gradually after experiencing “arise”.It’s noted that such similar phenomenon is also founded in other three inboard-type models,and there is no “rise” in the process of sinking about overlapping and outward-type roadway roof.The analyzed reason is probably that the arrangement of in-board type roadway is under the goaf and there is no restriction over the intermediate sandwich,once the stress make the intermediate sandwich move upward until keeping stable,it will subside due to gravity stress.

Figure 6(b),(c) record the process of two sides' offset where the offset is 0.43m and 0.3m off the centre of roadway respectively at the left and right side of roadway after final stability.In other in-board type models,both the two sides deviate toward the center of roadway,offset increased with staggered distance decreases and the range of increase is moderate.Offset of left and right side of roadway can reach 0.45m and 0.34m respectively when the staggered distance is 2m.Offset of left and right side in overlapping-type roadway is 0.68m and 0.01m respectively where the offset of left side is larger obviously toward center of roadway and the right side has no change nearly due to entity coal and rock at right side.Offset of two sides in outward-type roadway is not obvious except the staggered distance is 2m,which has larger damage and can not read the value,the offset is 0.08-0.14m at left side of roadway in other three models, the offset is 0.01-0.04m at right side of roadway.

4 CONCLUSION

Based on numerical simulation test and test results,the stability of bare roadway with different staggered distance was studied.Conclusions can be drew as follows:Of these ulter-closed mining roadway arrangement modes,global stability of the inboard type roadway is better based on the aspects of degree of damage,surrounding rock stress（σ_y and τ_{xy}）,changes of observation points etc;Roof subsidence in the inboard-type roadway is smaller,offset at two sides of roadway is larger,its offset direction approaches toward the centre of roadway,and offset increases with staggered distance decreases,the supporting of two sides is the central difficulty for in-board type roadway; The degree of damage in overlapping-type roadway is larger,and roof subsidence of overlapping-type is similar with the inboard-type roadway,while the deformation is large at left side,there are few changes at right side.The destructive deformation is maximum when the staggered distance of outward-type roadway is 2m,and degree of damage is decreases with the increase of staggered distance in outward-type roadway. Overall,roof subsidence in the outward-type roadway is larger,and two sides of it are basically stable.

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